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The effectiveness of vitamin and mineral premix and mineral mixture in treating hypocalcaemia in pregnant goats

M. M. Hotsuliak, V. V. Sakhniuk
mhotsuliak@btsau.edu.ua, volodymyr.sakhniuk@btsau.edu.ua

Bila Tserkva National Agrarian University, 8/1 Soborna str., Bila Tserkva, Kyiv region, 09117, Ukraine

ORCID:
M. M. Hotsuliak https://orcid.org/0009-0004-6165-5032
V. V. Sakhniuk https://orcid.org/0000-0002-3070-9876

Authors' Contributions:
HMM: Investigation; Data curation; Writing — original draft; Visualization; Formal analysis.
SVV: Project administration; Conceptualization; Methodology; Supervision; Writing — review & editing; Formal analysis.

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The aim of the study was to investigate the effectiveness of the vitamin and mineral premix "Koza Kitna" and the mineral mixture "Vita" in treating hypocalcaemia in pregnant goats. Experimental studies were conducted on pregnant animals in the experimental (n=12) and control (n=8) groups. The effectiveness of the preparations was determined based on the results of clinical and instrumental (echo osteometry) studies of goats, as well as laboratory blood tests at the beginning and end of the experiment. The content of total calcium and its ionised fraction in blood serum was determined using standardised methods, and the concentration of $25OHD_3$ was determined using an enzyme-linked immunosorbent assay with the *25-OH Vitamin D Total* (*Vit D-Direct*) test system. It has been established that feeding pregnant goats with the vitamin and mineral premix "Koza Kitna" and the mineral mixture "Vita" in daily doses of 50 and 40 g/head for 40 days contributed to the restoration of total calcium metabolism and its ionised fraction in the blood serum of 100.0 % of the animals in the experimental group. Feeding the control group goats the mineral mixture "Vita" at a dose of 40 g/head was ineffective. The results of the ROC analysis also indicate the high effectiveness of feeding these preparations to animals in the experimental group: the area under the ROC curve (AUC) was 1.0 (95 % CI: 0.832–1.0; sensitivity — 100.0 %; specificity — 100.0%; J-index — 100.0 %; P<0.001). At the end of the experiment, the calcidiol content in the blood serum of goats in the experimental group was 1.4 times higher than that of goats at the beginning of the experiment, and its values ranged from 18.0 to 32.4 ng/mL (23.7±2.31 ng/mL). Feeding the mineral mixture to the goats in the control group resulted in a slight increase in the level of 25-hydroxycolecalciferol in some of the animals, but its values were significantly lower than in the experimental group. At the end of the experiment, the speed of ultrasonic wave propagation in the experimental group of goats was significantly higher than at the beginning of the experiment and 26.2% higher than in the control group.

Key words: goats, total calcium, ionised calcium, $25OHD_3$, echoosteometry, hypocalcaemia, ROC analysis, Judin index

Introduction

Maintaining specialised goat farms with high genetic potential requires veterinary specialists knowledge of technological processes, as well as the specifics of treating and preventing diseases that arise from violations in the keeping and feeding of goats. One of the main reasons for the low realisation of the genetic potential of animals is

the insufficient provision of complete feed. One of the main problems is the imbalance of diets in terms of nutrients and biologically active substances, in particular the imbalance in the content of vitamins and macroelements [23, 32].

The development of new feed additives is an important factor in increasing productivity and maintaining the health of dairy herds. Premixes should ensure maximum absorption of biologically active substances and meet the physiological needs of dairy goats in terms of vitamin, macro- and microelement content. Therefore, the use of premixes is one of the most effective means of ensuring a balanced intake of vitamins and minerals into the animal's body [25].

Their use is particularly important during pregnancy, when metabolic processes in the animals' body undergo significant changes and require additional support. This period is crucial for maintaining the health and productive potential of goats. For example, during the last 2–3 weeks of pregnancy, dry matter intake does not meet the animals' needs for nutrients necessary for foetal development and lactogenesis, leading to energy deficiency. This metabolic imbalance significantly increases the susceptibility of goats to metabolic disorders. The most common metabolic diseases in goats are hypocalcaemia, alimentary osteodystrophy, toxicosis during pregnancy, hypo- and hypermagnaemia, which lead to a decrease in milk production and fertility disorders [4, 14, 40].

To prevent a decrease in calcium concentration in the bloodstream, the animal's body has three ways of maintaining its homeostasis: a) increasing calcium absorption in the gastrointestinal tract; b) enhancing its reabsorption from primary urine; c) mobilising it from bone reserves [37]. Parathyroid hormone (PTH) mobilises calcium from the bones, increases its reabsorption in the kidneys, and stimulates the synthesis of calcitriol — $1,25(OH)_2 D_3$ in the proximal tubules of the kidneys. At the same time, 1,25-dihydroxycholecalciferol activates the synthesis of calcium-binding protein (CaBP) in the mucous membrane of the small intestine, which stimulates calcium absorption [18].

Vitamin D is a key regulator of calcium metabolism and is important for the prevention and treatment of hypocalcaemia in ruminants. It belongs to the group of secosteroids and has anti-rickets properties. Formed in the kidneys under the action of enzymes (1α-hydroxylases), 1,25-dihydroxycolecalciferol has a decisive influence on calcium homeostasis, in particular by stimulating its absorption in the intestine [30]. According to Goff et al. [10], a decrease in the concentration of vitamin D receptors (VDR) in tissues during parturition can lead to a disruption in the ability of goats to respond to calcium requirements during early lactation, resulting in the development of hypocalcaemia. The reasons for the decrease in the number of vitamin D receptors (VDR) in the first hours after kidding have not been sufficiently studied. In addition, in animals with vitamin D deficiency, the efficiency of absorption of this macroelement in the intestine decreases [7].

The aim of the study is to investigate the effectiveness of vitamin-mineral premix and mineral mixture in hypocalcaemia in female goats.

Materials and Methods

The keeping, feeding, care of animals and all procedures were carried out in accordance with the Law of Ukraine "On the Protection of Animals from Cruel Treatment" (Kyiv, 2006, no. 1164-IV), "Basic Principles of the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes" (Strasbourg, France, 18 March 1986, ETS no. 123) and the "General Ethical Principles for Conducting Experiments on Animals", which were adopted at the First National Congress on Animal Bioethics (Kyiv, 2001). The research was conducted in compliance with all the principles of humanity provided for in the European Community Directive.

The microclimate in the premises during the research period complied with zoohygienic standards (DSTU 7823:2015 Animal farms. Requirements for microclimate parameters in premises for keeping animals).

Experimental studies on the effectiveness of vitamin-mineral premix and mineral mixture were conducted in winter on pregnant goats of the Saanen breed. For this purpose, two groups of animals were formed according to the principle of analogues: experimental (n=12) and control (n=8). Starting from 90–100 days of pregnancy, the goats in the experimental group were given a daily dose of 50 g/head of the vitamin and mineral premix "Koza Kitna" (MOLKAM LLC, Ukraine) and the mineral mixture "Vita" (Private Firm "Vita", Ukraine) at a rate of 40 g/head. One gram of the "Koza Kitna' premix contains vitamin A (760 IU), vitamin D_3 (140 IU), vitamin E (8 mg), calcium (0.09 g), phosphorus (0.035 g), magnesium (0.05 g), copper (1.2 mg), zinc (5.6 mg), manganese (4.8 mg), iodine (0.16 mg), cobalt (0.08 mg), selenium (0.045 mg). One gram of the "Vita" mineral mixture contains the macroelements calcium (0.25 g), phosphorus (0.15 g), magnesium (0.15 mg), sulphur (1.0 mg) and the microelements iron (0.3 mg), zinc (0.1 mg), and manganese (0.01 mg). The preparations were premixed with concentrated feed and fed for 40 days.

The control group of pregnant goats were given the "Vita" mineral mixture at similar stages of pregnancy, doses and feeding duration.

The effectiveness of vitamin and mineral supplements was determined based on the results of clinical and instrumental (echo osteometry) studies of animals, as well as laboratory blood tests at the beginning and end of the experiment. Clinical studies of goats were conducted according to the generally accepted scheme at the beginning and end of the experiment [20, 35]. In addition, the structure of the diet and its nutritional value were analysed [17, 31].

The material for the study was blood samples collected in disposable vacuum tubes with a blood coagulation activator and gel using the method of ante-mortem jugular vein puncture. Blood sampling was performed between 8:00 and 10:00 a.m. before feeding the animals. Before taking blood samples, the puncture site was shaved and

disinfected with a 96 % ethyl alcohol solution. The blood vessel was punctured with a disposable sterile *HENKE-JECT* injection needle (18G, 1.2×25 mm) at an angle of 45–50 ° away from the heart.

Biochemical analysis of goat blood serum was performed using standardised methods to determine the concentration of total calcium (reaction with calcium arsenate III) and ionised calcium (ion exchange absorption method) [19]. Measurements were performed using a *Stat Fax 4500+* biochemical analyser.

The concentration of $25OHD_3$ in the blood serum of goats was determined by enzyme-linked immunosorbent assay using the *Stat Fax analyser* (*Avareness Technology Inc.*, USA). The study was conducted using the *25-OH Vitamin D Total* (*Vit D-Direct*) test system (*Monobind Inc.*, USA) [12, 39] at the interfaculty research laboratory for molecular genetic and immunological studies at the Bila Tserkva National Agrarian University.

The speed of ultrasound propagation through the bone tissue of goats was determined using an *EOM-01-C* echo osteometer. The study was conducted on the last ribs of goats along the meral line.

The results of biochemical studies are presented in accordance with the International System of Units (SI), which is recommended for use in clinical laboratory practice [19]. Data analysis was performed using the *Statistica 12.0* software package (*StatSoft Inc.*, USA, 2014). The arithmetic mean (M) and statistical error of the arithmetic mean (m) were determined, and Pearson's correlation coefficient (r) was calculated. The normality of the distribution of indicators was tested using the Shapiro-Wilk test, and the equality of variance was tested using the Levene criterion. Student's *t*-test was used to compare the differences between the mean values. The results were considered significant at $P<0.05$; 0.01; 0.001 [8, 29, 33].

To evaluate the effectiveness of vitamin and mineral supplements, ROC analysis was used to determine the area under the ROC curve (AUC). An AUC value of up to 0.5 indicates low discriminatory power, while an increase to 1.0 indicates high accuracy in distinguishing between the experimental and control groups of animals. This test reflects the dependence of the number of correctly and incorrectly classified cases with a 95 % confidence interval (95 % CI) [13].

Using the optimal threshold value, we calculated sensitivity, specificity, and the Youden index (J). This index ranges from 0 to 1 (or from 0 to 100 %), with values closer to 1 indicating high effectiveness of the indicator, and a decrease in the index indicating low test informativeness [15].

Results and Discussion

Clinical and experimental studies were conducted from December 2023 to February 2024 on Saanen goats in their second to fourth lactation. One of the important elements of a comprehensive assessment of the clinical status of goats is the determination of their body condition, which was carried out using the BCS scale in the range from 1.0 to 5.0 with a step of 0.5 points (Body Condition Score) [9, 11]. It was found that 75.0 % of the goats in the experimental and control groups were of average body condition (2.5–3.5 points on the BCS), and another 25.0 % were below average (1.5–2.0 points). Body condition (BCS) was determined by examination and palpation of fat deposits in the lumbar spine, ribs and sternum. In 75.0 % of the goats, the general condition was satisfactory, and the body position in space was natural standing. The coat was shiny, evenly covered the skin and was well retained. The skin of most animals was pale pink, elastic, and moderately moist. The conjunctiva was predominantly pale pink in colour and moderately moist. The mucous membranes of the oral cavity and nose were moderately moist and pale pink. The superficial lymph nodes (submandibular, prescapular, popliteal and supraclavicular) are not enlarged, smooth, mobile, painless, dense in consistency, and the skin temperature in the areas of their localisation did not differ from the temperature of the adjacent tissues. The pulse rate in goats was 68–80 beats per minute, respiratory rate was 16–28 breaths per minute, and body temperature was 38.5–39.6 °C. In addition, 25.0 % of animals were diagnosed with slight depression of general condition, decreased body weight and appetite, dullness and matting of the coat, pallor of the visible mucous membranes, looseness of the incisors, humpiness, lysis of the last pairs of ribs and tail vertebrae, slight tachycardia and tachypnoea.

The daily diet of pregnant goats included the following feeds: meadow hay (1.2 kg), granulated mixed feed (1.0 kg), which consisted of corn (0.35 kg), wheat (0.18 kg), oats (0.16 kg), sunflower meal (0.21 kg), and soybean meal (0.10 kg). The diet of the goats was sufficient in crude protein (104.6 % of the requirement) and digestible protein (106.6 %) with a significant excess of magnesium (143.0 %). At the same time, the diet is deficient in dry matter (92.1 %), metabolisable energy (85.7 %), feed units (78.6 %), crude fibre (89.6 %), crude fat (66.3 %), sugar (48.3 %), starch (64.6 %), calcium (74.5 %), phosphorus (66.1 %) and manganese (96.8 %), and trace elements — zinc (67.6 %), copper (75.0 %), cobalt (52.8 %), iodine (53.5 %), vitamins A and D (35.0 % and 48.5%, respectively). The calcium-phosphorus ratio was 1.59:1 compared to 1.78:1 according to the norm [24]. The ratio of sugar to digestible protein and the sum of easily fermentable carbohydrates (sugar and starch) to digestible protein were 0.36:1 and 1.95:1, respectively. In the diet structure (by metabolisable energy), roughage accounted for 40.5 % (optimally 35–45 %), concentrates — 59.5 % (the norm is 20–22.0 % [17]), and there was no succulent feed. The concentration of crude and digestible protein in 1 kg of dry matter of the diet was 8.3 and 6.0 %, respectively, and crude fibre was 11.6 %.

Based on the results of biochemical studies, we found that the concentration of total calcium in the blood serum of goat kids at the beginning of the experiment ranged

Table 1. Dynamics of total calcium when feeding vitamin-mineral premix and mineral mixture to pregnant goats

Biochemical indicator	Research	Biometric indicator	Groups of animals		
			experimental	control	P<
Total calcium, mmol/L	1	n	12	8	
		Lim	2.01–2.27	1.70–2.20	
		M±m	2.1±0.03	2.0±0.06	0.1
	2	n	12	8	
		Lim	2.22–2.69	1.68–2.05	
		M±m	2.4±0.04	1.8±0.04	0.001
		P_1<	0.001	0.01	

Table 2. Dynamics of ionised calcium when feeding vitamin-mineral premix and mineral mixture to pregnant goats

Biochemical indicator	Research	Biometric indicator	Groups of animals		
			experimental	control	P<
Ionized calcium, mmol/L	1	n	12	8	
		Lim	0.46–0.82	0.42–0.65	
		M±m	0.6±0.04	0.5±0.03	0.05
	2	n	12	8	
		Lim	0.64–1.17	0.51–0.74	
		M±m	1.0±0.05	0.6±0.03	0.001
		P_1<	0.001	0.05	

Note. Here and further: 1 — start of the experiment (90–100 days of pregnancy); 2 — end of the experiment (135–145 days of pregnancy). P< — significance of values between the experimental and control groups; P_1< — significance of values between the start and end of the experiment.

from 1.70 to 2.27 mmol/L (2.1±0.03 mmol/L), including 2.01–2.27 mmol/L (2.1±0.03 mmol/L) in the experimental group and 1.70–2.20 mmol/L (2.0±0.06 mmol/L) in the control group (P<0.1) (table 1). In 41.7 % of goats in the experimental group and 12.5 % in the control group, the macroelement content was optimal, while in 58.3 % and 62.5 % of animals, respectively, its values were close to the lower limit of the norm.

After feeding the vitamin-mineral premix and mineral mixture, the concentration of total calcium in the blood serum of goats in the experimental group was 1.14 times higher than that of animals at the beginning of the experiment (P<0.001) ranging from 2.22 to 2.69 mmol/L (2.4±0.04 mmol/L) (see table 1). Analysis of individual indicators showed that in all goats, the level of the macroelement was 11.8–30.6 % higher than at the beginning of the experiment, and its maximum values reached 2.51–2.69 mmol/L, which indicates the high therapeutic efficacy of combined feeding of these preparations for hypocalcaemia in pregnant goats. A positive correlation of moderate strength (r = +0.36) was established between the concentration of total calcium in the blood serum of goats in the experimental group at the beginning of the experiment and at its completion.

In the control group, a marked decrease in total calcium content was observed at the end of the experiment, with its concentration varying in the range of 1.68–2.05 mmol/L (1.8±0.04 mmol/L), which is 25.0 % less than in the experimental group (P<0.001) and 10.0 % less than at the beginning of the experiment (P<0.01) (see table 1).

To evaluate the effectiveness of drugs based on the concentration of total calcium in the blood serum of goats at the end of the experiment, we performed a ROC analysis between the experimental and control groups. It was found that the optimal threshold value of total calcium concentration in goats of the experimental and control groups was ≤2.05 mmol/L, the area under the curve (AUC) was 1.0 (95 % confidence interval: 0.832–1.0). The analysis of this test indicates the high effectiveness of feeding these preparations to goats in the experimental group compared to the control group, since the test values were significant, in particular, sensitivity — 100.0 %, specificity — 100.0 % and J-index — 100.0 % (P<0.001) (fig. 1).

Thus, feeding pregnant goats with the vitamin and mineral premix “Koza Kitna” and the mineral mixture “Vita” in daily doses of 50 and 40 g/head for 40 days contributed to the restoration of total calcium metabolism in the blood serum of animals in the experimental group. Feeding the goats in the control group the mineral mixture “Vita” at a dose of 40 g/head did not lead to an increase in total calcium concentration and was ineffective.

The next stage of the work was to study changes in the concentration of the ionised fraction of calcium when feeding animals with vitamin and mineral preparations. Thus, the level of ionised calcium in the blood serum of pregnant goats at the beginning of the experiment was within the range of 0.42–0.82 mmol/L (0.6±0.03 mmol/L), in particular, in the experimental group it was 0.46–0.82 mmol/L (0.6±0.04 mmol/L), in the control group — 0.42–0.65 mmol/L (0.5±0.03 mmol/L; P<0.05) (table 2). In 91.7 % of goat kids in the experimental group and 62.5 % in the control group, the content of the ionised fraction of the macroelement was optimal.

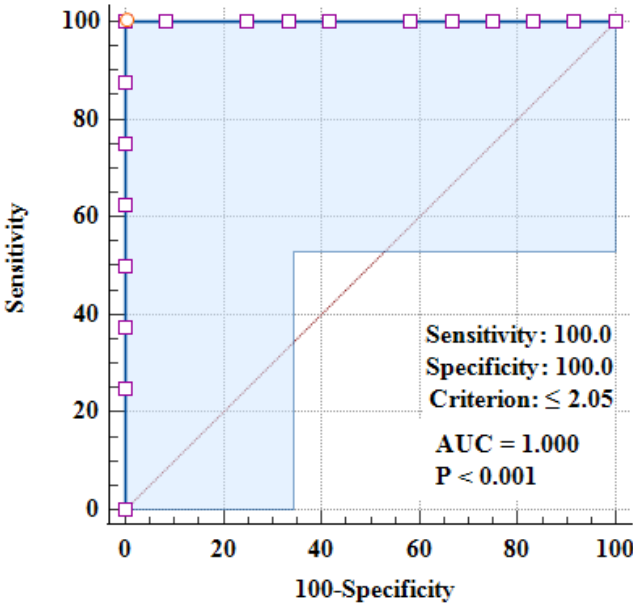

Fig. 1. ROC curve for the use of vitamin and mineral supplements in pregnant goats in the experimental and control groups based on total calcium concentration in blood serum at the end of the experiment (n=20)

At the end of the experiment, the concentration of ionised (free) calcium fraction in the blood serum of experimental group goats was 66.7 % higher compared to the beginning of the experiment (P<0.001) ranging from 0.64 to 1.17 mmol/L (1.0±0.05 mmol/L) (see table 2). In all animals, the level of ionised calcium was 25.9–45.8 % higher than at the beginning of the study, and its values in all animals in this group were optimal and reached 1.09–1.18 mmol/L. There was a positive correlation (r = +0.17) between the levels of ionised calcium in the blood serum of goats in the experimental group at the beginning and end of the study. There was a high correlation between the values of total calcium and its ionised fraction at the end of the experiment (r = +0.78).

At the end of the experiment, 87.5 % of the animals in the control group were diagnosed with a tendency to increase the concentration of free calcium (0.6±0.03 mmol/L), and its values ranged from 0.51 to 0.74 mmol/L, which is 40.0 % less than in the experimental group (P<0.001) (see table 2).

According to the results of ROC analysis, the optimal threshold value of ionised calcium concentration in the blood serum of goats in the experimental and control groups at the end of the experiment was ≤0.74 mmol/L, with an area under the curve (AUC) of 0.948 (95 % confidence interval: 0.748–0.999). The analysis confirms the high level of effectiveness of the vitamin-mineral premix and mineral mixture in animals of the experimental group compared to the control group, as the indicators of this test were high: sensitivity — 100.0 %; specificity — 91.7 %; J-index — 91.7 % (P<0.001) (fig. 2).

Thus, feeding the vitamin and mineral premix "Koza Kitna" and the mineral mixture "Vita" in daily doses of 50 and 40 g/head for 40 days contributed to a significant increase

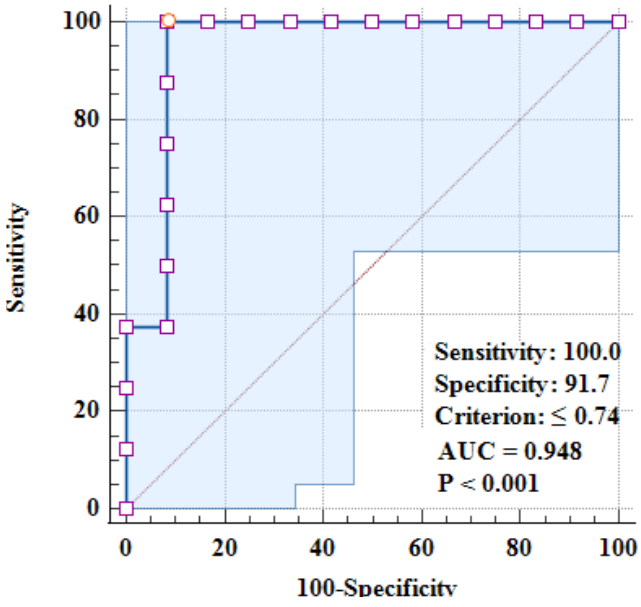

Fig. 2. ROC curve for the use of vitamin and mineral supplements in pregnant goats in the experimental and control groups based on the concentration of ionised calcium in blood serum at the end of the experiment (n=20)

Table 3. Calcidiol dynamics when feeding vitamin-mineral premix and mineral mixture to lactating goats

Biochemical indicator	Research	Biometric indicator	Groups of animals		
			experimental	control	P<
$25OHD_3$, ng/mL	1	n	7	3	
		Lim	13.4–20.8	10.9–15.0	
		M±m	16.9±1.15	13.0±1.19	0.05
	2	n	7	3	
		Lim	18.0–32.4	11.0–19.9	
		M±m	23.7±2.31	16.3±2.11	0.1
		P_1<	0.05		

in ionised calcium in the blood serum of 100.0 % of the animals in the experimental group compared to the beginning of the experiment. Feeding the control group of goats a mineral mixture at a dose of 40 g/head in terms of free calcium content during the same period was ineffective.

One of the stages of the study was to investigate the dynamics of the metabolism of one of the active metabolites of vitamin D, $25OHD_3$, in the blood serum of pregnant goats in the experimental and control groups when fed the above preparations. It was found that the concentration of calcidiol in pregnant goats at the beginning of the experiment ranged from 10.9 to 20.8 ng/mL (15.7±0.94 ng/mL), including 13.4–20.8 ng/mL (16.9±1.15 ng/mL) in the experimental group and 10.9–15.0 ng/mL (13.0±1.19 ng/mL) in the control group (P<0.05) (table 3).

At the end of the experiment, the concentration of 25-hydroxycolecalciferol in the blood serum of goats in the experimental group was 1.4 times higher than at the beginning of the experiment (23.7±2.31 ng/mL; P<0.05) (see table 3). It was found that in almost all animals, the content of $25OHD_3$ was higher than at the beginning of the experiment, and its maximum values reached 27.2–32.4 ng/mL, which indicates a positive effect of these drugs on the metabolism of calcidiol, total calcium and its ionised fraction in pregnant goats. A positive correlation (r = +0.20) was established between the 25-hydroxycolecalciferol levels at the beginning and end of the experiment.

The level of $25OHD_3$ in goats of the control group at the end of the experiment was in the range of 11.0–19.9 ng/mL (16.3±2.11 ng/mL) and was 31.2 % lower than the values of the experimental group (P<0.05) (see table 3). All animals studied showed a slight increase in calcidiol concentration by 0.9–50.8 %, up to 11.0–19.9 ng/mL, but its values were significantly lower than in the experimental group of goats.

According to the results of studies and ROC analysis, the optimal threshold value of 25-hydroxycolecalciferol concentration in the blood serum of goats in the experimental and control groups at the end of the experiment was ≤17.9 ng/mL, with an area under the curve (AUC) of 0.857 (95 % CI: 0.505–0.991). The analysis of this test indicates the high effectiveness of feeding vitamin and mineral supplements to animals in the experimental group compared to the control group (sensitivity — 66.7 %; specificity — 100.0 %; J-index — 66.7 %; P<0.05) (fig. 3).

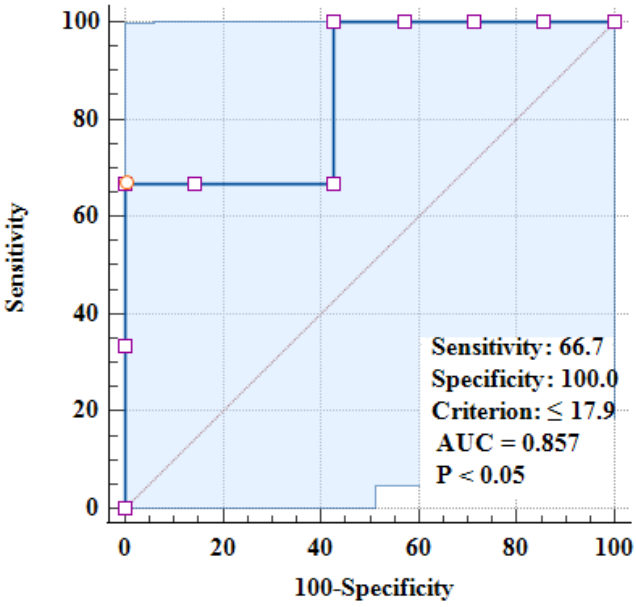

Fig. 3. ROC curve for the use of vitamin and mineral supplements in pregnant goats in the experimental and control groups based on the concentration of $25OHD_3$ in blood serum at the end of the experiment (n=10)

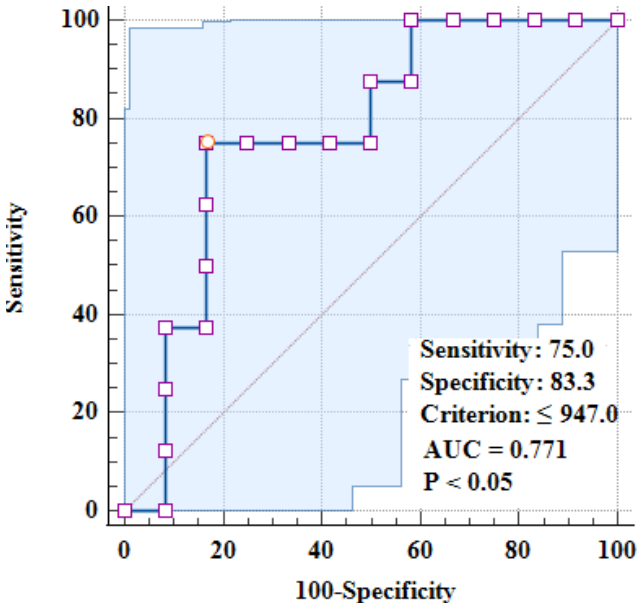

Fig. 4. ROC curve for the use of vitamin and mineral supplements in pregnant goats in the experimental and control groups based on the speed of ultrasound wave propagation across the area of the last ribs at the end of the experiment (n=20)

Thus, the use of the vitamin-mineral premix "Koza Kitna" and the mineral mixture "Vita" for goats in the experimental group contributed to a significant increase in calcidiol in the blood serum of 100.0 % of animals. Feeding the mineral mixture to the goats in the control group resulted in a slight increase in $25OHD_3$ levels, but these values were significantly lower than in the animals in the experimental group.

The speed of ultrasound wave propagation in the area of the last ribs in goats was assessed at the beginning and end of the experiment using the "Echo Osteometer" EOM-01-C in the mode of absolute time measurement at a distance of 25 mm between the diagnostic heads of the echo osteometer and an ultrasonic wave frequency of 0.12 MHz. According to the results of echo osteometry, it was established that the speed of ultrasound propagation in the area of the last ribs in the goats of the experimental group at the beginning of feeding the preparations was 1264.0±105.34 m/s (633.0–1724.1 m/s), in the control group — 1046.5±104.36 m/s (769.2–1534.0 m/s) (table 4), and the difference between the values was insignificant (P<0.2).

Table 4. Echoosteometry indicators in pregnant goats fed with vitamin-mineral premix and mineral mixture

Indicator	Research	Biometric indicator	Groups of animals		
			experimental	control	P<
Ultrasonic wave velocity, m/s	1	n	12	8	
		Lim	633.0–1724.1	769.2–1534.0	
		M±m	1264.0±105.34	1046.5±104.36	0.2
	2	n	12	8	
		Lim	718.4–1908.4	733.1–1437.0	
		M±m	1329.0±117.20	981.0±93.66	0.05
		P_1<	0.5	0.5	

At the end of the experiment, 91.7 % of animals in the experimental group showed a tendency to increase the speed of the ultrasound wave (1329.0±117.20 m/s) (see table 4), and its values were on average 5.1 % higher than at the beginning of the study. In goats of the control group, the ultrasound velocity was 26.2 % lower than in animals of the experimental group (P<0.05) and showed a pronounced tendency to decrease compared to the beginning of the experiment (see table 4). High positive correlations were found between the ultrasound velocity values of the experimental and control groups between the beginning and end of the experiment (r = +0.94 and r = +0.74, respectively).

According to the results of ROC analysis, the optimal threshold value of ultrasound propagation velocity in the area of the last ribs in the experimental and control groups at the end of the experiment was ≤947.0 m/s, the area under the curve (AUC) was 0.771 (95 % confidence interval: 0.531–0.926). The results obtained indicate the high effectiveness of the drugs used in the experimental group of animals compared to the echoosteometry indicators of the control group, as indicated by the test results (sensitivity — 75.0 %; specificity — 83.3 %; J-index — 58.3 %; (P<0.05) (fig. 4).

Thus, feeding vitamin and mineral supplements to the experimental group of goats contributed to an increase in the speed of ultrasonic waves in bone tissue in 91.7 % of animals. In 87.5 % of the control group, echoosteometry values showed a marked downward trend.

Balanced feeding is the key to animal health and long-term productive use, which ultimately determines the profitability of the industry. An unbalanced mineral supply in goat diets often leads to metabolic disorders. The

most common metabolic disorder in goats is hypocalcaemia [40]. According to Bayoumi et al. [3] and Simões et al. [34], hypocalcaemia in goats is usually diagnosed several weeks before and after kidding, and the mechanism underlying the development of this pathology is a sharp or gradual decrease in the concentration of calcium in the blood serum of animals, and compensation for calcium deficiency by its intake from mineral deposits leads to demineralisation of the animals' bone tissue [6].

Research on calcium concentration in the diet of pregnant goats is limited, and specific recommendations for the prevention of this pathology in these animals are almost non-existent. According to Liesegang et al. [21], clinical signs of hypocalcaemia in goats are recorded several weeks before and after kidding. The development of this disease in goats is due to the high calcium requirement during pregnancy for foetal development and preparation of the body for lactation. The macroelement requirement for goats during pregnancy is 10.5 g, while after kidding it is up to 30.5 g per day [22].

Currently, the optimal amount of calcium in the diet of animals during the prenatal period is a matter of debate. Brugger and Liesegang [5] reported that with a calcium content of 0.6 % and 1.3 % in 1 kg of dry matter in the diet of pregnant goats, no development of postpartum hypocalcaemia was observed. However, in the blood serum of lactating goats in the experimental group, which were fed more calcium, an increase in osteocalcin levels was observed, which is one of the main markers in bone formation and delayed development of young animals.

A similar pattern was established by Lean et al. [18] in cows, where the authors note that the optimal calcium content should be no more than 1.1 % and no less than 1.5 % in 1 kg of the dry matter of the animal's diet, since at a concentration of 1.35 % calcium, the highest incidence of hypocalcaemia was observed in high-yielding cows.

The main objective of our work was to study the effectiveness of vitamin and mineral premix and mineral mixture in hypocalcaemia in pregnant goats.

According to the results of our research, the use of the vitamin-mineral premix "Koza Kitna" and the mineral mixture "Vita" in daily doses of 50 and 40 g/head for 40 days in the experimental group of pregnant goats for 40 days contributed to the restoration of total calcium metabolism and its ionised fraction in the blood serum of 100.0 % of the animals in the experimental group.

One of the vital fat-soluble vitamins for animals is calciferol. The main function of this vitamin is to increase the concentration of calcium in the blood plasma to a level that maintains optimal mineralisation of bone tissue, as well as other vital functions of the body. In particular, in ruminants with optimal calcium supply in their diet, vitamin D stimulates bone formation and mineralisation, and in hypocalcaemia, it enhances calcium mobilisation from bone tissue and its absorption in the intestine [1, 16].

According to many authors [27, 28, 36], the optimal level of the active metabolite of vitamin D — $25OHD_3$ in the blood serum of ruminants is within the range of 30–60 ng/mL, while values below 10 ng/mL indicate a deficiency of this vitamin.

It was found that the use of vitamin and mineral supplements in the experimental group of goats contributed to a significant increase in the content of calcidiol in the blood serum of 100.0 % of animals. Feeding the mineral mixture to the goats in the control group resulted in a slight increase in $25OHD_3$ levels, but the values were significantly lower than in the experimental group.

Similar studies have been conducted on other animals. In particular, according to the results of studies by Nelson et al. [26], adding cholecalciferol to the basic diet of high-yielding cows at a dose of 0.75 to 1.25 mg/day (30,000 to 50,000 IU/day), mainly to maintain calcium and phosphorus homeostasis in the body, led to an increase in the level of this fat-soluble vitamin in the blood serum to 60–80 ng/mL, which was not observed in the control group animals. When 20,000 IU/day was added, the $25OHD_3$ values were significantly lower (42.0±15.0 ng/mL), with 22 % of cows having active metabolite levels below 30 ng/mL. According to Xu et al. [38], for the prevention of subclinical hypocalcaemia, cows were given oral boluses of calcium (90 g of calcium) and cholecalciferol (240 mg/day) were administered orally to cows during the dry period and in the first hour after calving to prevent subclinical hypocalcaemia, which significantly increased the serum concentration of total calcium, ionised calcium and the active metabolite of vitamin D — $25OHD_3$. The authors note that with this prevention regimen, the experimental cows showed an increase in milk yield and improvement in their general condition due to the suppression of oxidative stress and inflammatory reactions, as well as an increase in IgG levels.

According to Bandarra et al. [2], the speed of ultrasound propagation through bone tissue depends on its density, since the structure and porosity of bone affect the scattering and attenuation of ultrasound waves. Our research has shown that the speed of ultrasound propagation through the last ribs in the experimental group of goats at the end of the experiment had a pronounced tendency to increase in all animals. The use of a mineral mixture at a dose of 40 g/head in the control group of goats was ineffective, since in 87.5 % of animals, echoosteometry values showed a marked tendency to decrease.

Feeding vitamin-mineral premix and mineral mixture to experimental group goats for 40 days contributed to a significant increase in the concentration of total calcium and ionised calcium in blood serum, respectively, by 1.14 and 1.68 times compared to the beginning of the experiment and was effective in treating goats with hypocalcaemia.

The addition of a mineral mixture to the basic diet of goats in the control group was ineffective, since the values of total calcium and its ionised fraction in the blood serum of animals were 25.0 and 40.0 % lower, respectively, compared to the experimental group.

The use of vitamin and mineral preparations in the experimental group of goats contributed to a 1.40-fold

increase in the concentration of calcidiol in the blood serum compared to the beginning of the experiment. Feeding the mineral mixture to goats in the control group resulted in a slight increase in $25OHD_3$ content, but its values were significantly lower than in goats in the experimental group.

The speed of ultrasonic wave propagation through the bone tissue of animals in the experimental group tended to increase at the end of the experiment compared to the beginning of the experiment. In the control group of goats, the speed of ultrasound was 26.2 % lower than in the experimental group and showed a marked tendency to decrease compared to the beginning of the experiment.

According to the results of the ROC analysis conducted at the end of the experiment, a statistically significant difference was found between the indicators of total calcium, ionised calcium, calcidiol and echoosteometry in the goats of the experimental and control groups: the Yuden index when comparing the concentration of total calcium was 100.0 %, ionised calcium — 91.7 %, calcidiol — 66.7 % and 58.3 % between echo-osteometry values.

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Ефективність вітамінно-мінерального премікса та мінеральної суміші за гіпокальціємії у кітних козематок

М. М. Гоцуляк, В. В. Сахнюк
mhotsuliak@btsau.edu.ua, volodymyr.sakhniuk@btsau.edu.ua

Білоцерківський національний аграрний університет, вул. Соборна, 8/1, м. Біла Церква, Київська обл., Україна

Метою дослідження було вивчення ефективності вітамінно-мінерального премікса «Коза кітна» та мінеральної суміші «Vita» за гіпокальціємії у кітних козематок. Експериментальні дослідження проводили на кітних тваринах дослідної (n=12) та контрольної груп (n=8). Ефективність препаратів визначали на основі результатів клінічного та інструментального (ехоостеометрія) досліджень козематок, а також лабораторного аналізу крові на початку експерименту та по його завершенні. У сироватці крові уніфікованими методами визначали вміст кальцію загального та його іонізованої фракції, концентрацію $25OHD_3$ — методом імуноферментного аналізу за використання тест-системи «25-OH Vitamin D Total (Vit D-Direct)». Встановлено, що згодовування кітним козематкам вітамінно-мінерального премікса «Коза кітна» і мінеральної суміші «Vita» у добових дозах 50 і 40 г/гол. впродовж 40 діб сприяло відновленню метаболізму кальцію загального та його іонізованої фракції у сироватці крові 100,0 % тварин дослідної групи. Згодовування козам контрольної групи мінеральної суміші «Vita» у дозі 40 г/гол. було малоефективним. Результати ROC-аналізу також свідчать про високу ефективність згодовування зазначених препаратів тваринам дослідної групи: площа під ROC-кривою (AUC) становила 1,0 (95 % ДІ: 0,832–1,0; чутливість — 100,0 %; специфічність — 100,0 %; індекс J — 100,0 %; P<0,001). По завершенні експерименту вміст кальцидіолу у сироватці крові кіз дослідної групи був в 1,4 раза вищим порівняно з козематками на початку досліду, а його значення коливалися в межах 18,0–32,4 нг/мл (23,7±2,31 нг/мл). Згодовування козематкам контрольної групи мінеральної суміші зумовило незначне підвищення рівня 25-гідроксихолекальциферолу у частини тварин, проте його величини були достовірно менші ніж у дослідній групі. По завершенні експерименту швидкість поширення ультразвукової хвилі у кітних козематок дослідної групи була достовірно вищою, ніж на початку досліду, та на 26,2 % більшою проти значень у тварин контрольної групи.

Ключові слова: кози, кальцій загальний, кальцій іонізований, $25OHD_3$, ехоостеометрія, гіпокальціємія, ROC-аналіз, індекс Юдена

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